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# DESIGN OF OPTIMAL PID CONTROLLER OF PH NEUTRALISATOR BASED ON ANFIS MODEL OF PH NEUTRALISATOR

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## ABSTRACT
*In this paper is presented ANFIS (Adaptive Network based Fuzzy Inference System) method of modeling of pH neutralisator. Data that has been used for training of ANFIS are obtained by performing experiments on a real pH neutralisator. The mathematical model of the pH neutralisator is strongly nonlinear so it is advisable to use ANFIS, since ANFIS is an universal approximator. Inputs of the process (control variables) are flow of acid and hydroxide. The working temperature of the process is $128^0C$, with instaled pH meter of operating range 2-12 pH with combined glass electrode in the upper part of the neutralizer, 20 cm bellow the surface. Then using Genetic Algorithms (GA) parameters of PID controller of pH value has been adjusted in optimal way. Since GA is method of search of global optimum, achieved solution is optimal according to integral criterion of performance. Simulation results show utility of the proposed methodology.*
**Keywords:** ANFIS, pH value control, PID controller, Genetic Algorithms, Fuzzy Inference System.

## 1. INTRODUCTION
In the first part of this paper model of both, hydroxide and acid chanel of pH neutralisator, has beed determinated using ANFIS (Adaptive Network based Fuzzy Inference System) proposed by Roger Jang. Mathematical model of the pH neutralisator is strongly nonlinear, so it is advisable to use ANFIS, since ANFIS is an universal approximator. Data that has been used for training of ANFIS structure are obtained in experimental vay, and some of trainig data has been shown in figures 1, 2 and 3. In second part of this paper desing of an optimal PID controller of the pH neutralisator based on ANFIS model of the neutralisator is performed. Parameters of the PID controller have been adjusted using Genetic Algorithms. Inputs of the process are: distilled acid and hydroxide solution. The working temperature in process is 128°C, with installed pH-meter of operating range 2-12 pH with combined glass electrode; in the upper part of neutralisator 20cm bellow the level.
Registrations of acid and hydroxide flow are shown on the Figure 1. Initial pH values are given at figure 2. In the figure 3 the sample of output subsystem of pH acid is presented.

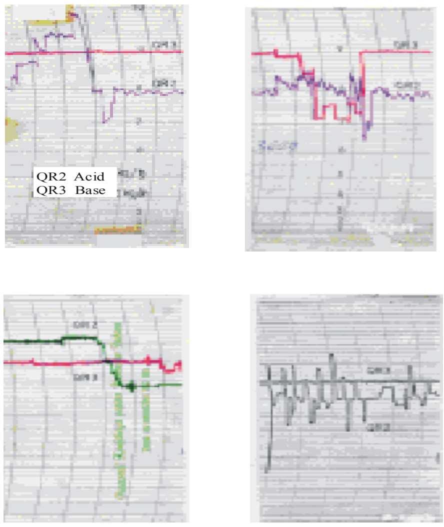

*Figure 1. Marking of acid and hydroxide flows*

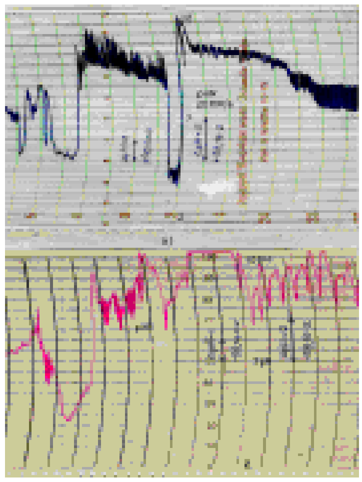
*Figure 2. pH diagrams*

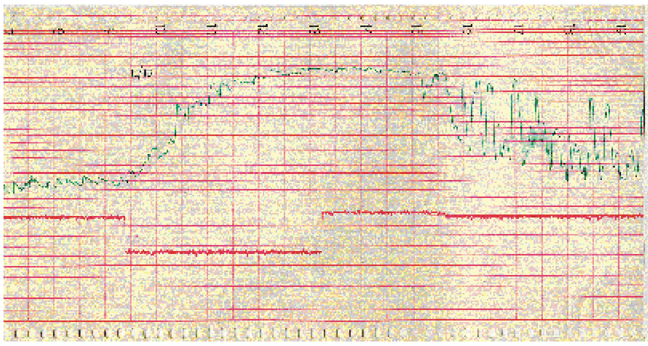
*Figure 3. The sample of experimental output for subsystem of pH-acid*

## 2. ANFIS IDENTIFICATION

As input of ANFIS structure has been used delayed input and output. Using extensive simulation has been concluded that optimal delay, which is multiple of number of sampling period (1 second), of input signal is 7, and output signal is 1. So model of pH neutralisator (both channels) can be described by some nonlinear function (that is approximated by ANFIS structure) of the form:

$$y(k\cdot\Delta t) = f(y((k-1)\cdot\Delta t), u((k-7)\cdot\Delta t)) \qquad (1)$$

where $y$ is output of the channel, $u$ is control signal (input of channel), $\Delta t$ is sampling interval and $f$ is some nonlinear function approximated by ANFIS. Each of two inputs (delayed $y$ and delayed $u$) of the ANFIS (Fuzzy) model of both channels has three Gaussian membership functions, and output layer of ANFIS structure is realized using linear functions (Sugeno type of fuzzy inference system (FIS)). Input membership functions of both $y$ and $u$ before and after ANFIS training are shown in figure 4. ANFIS structure was trained in 300 epochs. ANFIS structure (for hydroxide channel) that were obtained is represented by the following Matlab code:

[System], Name='anfisstruct' ,Type='sugeno', Version=2.0, NumInputs=2, NumOutputs=1, NumRules=9, AndMethod='prod', OrMethod='max' , ImpMethod='prod', AggMethod='max', DefuzzMethod='wtaver', [Input1], Name='input1', Range=[-1 1], NumMFs=3,
MF1='in1mf1':'gaussmf',[0.377952171794255 -0.970117289663212],
MF2='in1mf2':'gaussmf',[0.478100017862741 0.209810656036424],
MF3='in1mf3':'gaussmf',[0.643129485939259 1.06544016559141], [Input2], Name='input2', Range=[-2.03689746149264 1.37087868680647], NumMFs=3,
MF1='in2mf1':'gaussmf',[0.807036766360507 -1.92592549978252],

MF2='in2mf2':'gaussmf',[0.430112903865081 -0.152123675227793],
MF3='in2mf3':'gaussmf',[0.672788865208858 1.39229408829372]
[Output1], Name='output', Range=[-2.03689746149264 1.37087868680647], NumMFs=9,
MF1='out1mf1':'linear',[0.0177618910945297 0.999414951208204 -0.0535140170605092],
MF2='out1mf2':'linear',[-0.11342843443282 0.960352259765125 -0.160257738445848]
MF3='out1mf3':'linear',[-0.0526929173530097 0.960884376674386 -0.0422519595975257]
MF4='out1mf4':'linear',[-0.128618258936927 1.1060637557168 7 -0.212988504521436]
MF5='out1mf5':'linear',[-0.21542564456912 1.08135242468325 -0.125835001409057]
MF6='out1mf6':'linear',[-0.075933856072987 1.07926160581106 -0.169260027408112]
MF7='out1mf7':'linear',[-0.963908745947364 0.880065058713415 0.985633232582456]
MF8='out1mf8':'linear',[-0.416005951543612 0.933255719510807 0.532831106470468]
MF9='out1mf9':'linear',[-0.246475158947163 0.938982688187477 0.373902712662496]
[Rules], 1 1, 1 (1) : 1, 1 2, 2 (1) : 1, 1 3, 3 (1) : 1, 2 1, 4 (1) : 1, 2 2, 5 (1) : 1, 2 3, 6 (1) : 1, 3 1, 7 (1) : , 3 2, 8 (1) : 1, 3 3, 9 (1) : 1

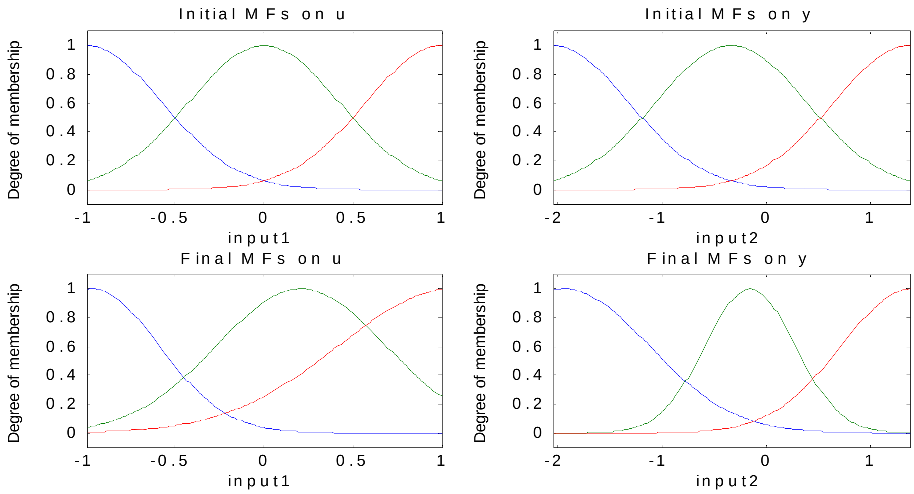


*Figure 4. Membership functions before and after training*

### 3. PID CONTROLLER DESIGN

In this paper parameters of PID controllers (figure 5) are adjusted according to integral performance of criterion given by formula 1.

$$J = \int_0^t \left[ e^2(t) + r(u_H^2(t) + u_A^2(t)) \right] dt \qquad (2)$$

where $e$ is error (input minus output), $u_H$, $u_A$ are control signals, and $r$ is cost parameter.
Cost parameter $r$ is chosen as $r$ = 0.01. GA with SUS type of selection, two point crossover and mutation has been used. Simulation is performed for 60 seconds. Optimal values of PID parameters have been searched in region that is chosen according to characteristics of the process and considering practical realization of controller and is given as:
$k_{pH} \in [0\ 1]$, $k_{iH} \in [0\ 1]$, $k_{dH} \in [0\ 1]$, $k_{pA} \in [0\ 1]$, $k_{iA} \in [0\ 1]$ i $k_{dA} \in [0\ 1]$.
Achieved control parameters are given as:

$$G_{PIDH} = 0.55 + 0.019 \cdot \frac{1}{s} + 0.39 \cdot s \qquad (3)$$

$$G_{PIDA} = 0.001 + 0 \cdot \frac{1}{s} + 0.25 \cdot s \qquad (4)$$

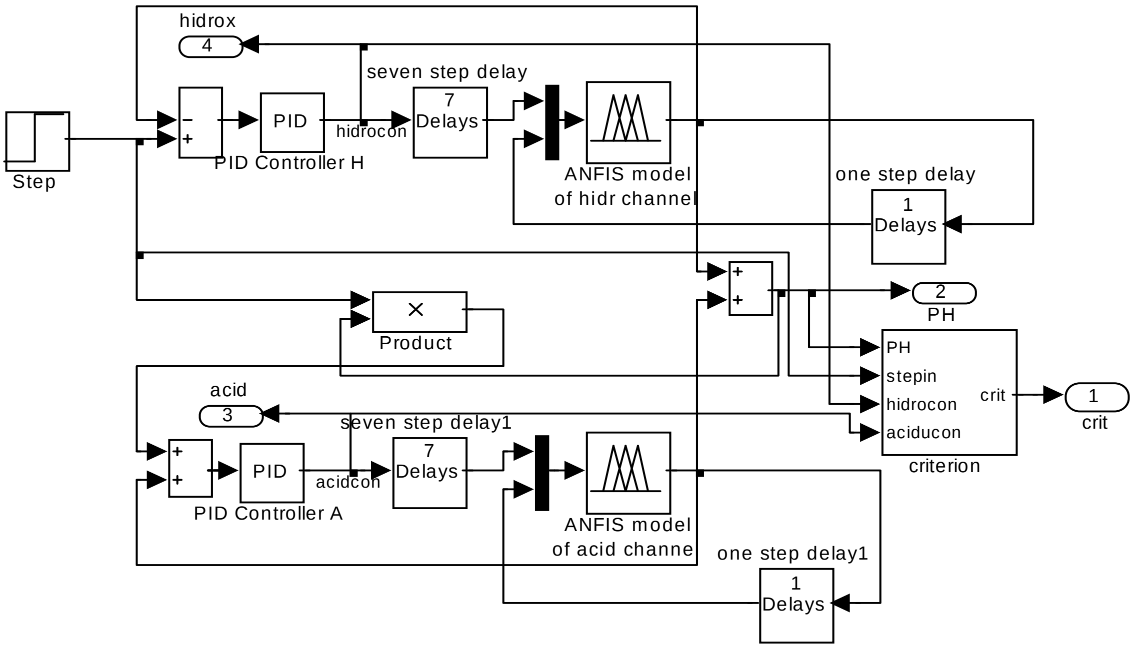


*Figure 5. Simulation model*

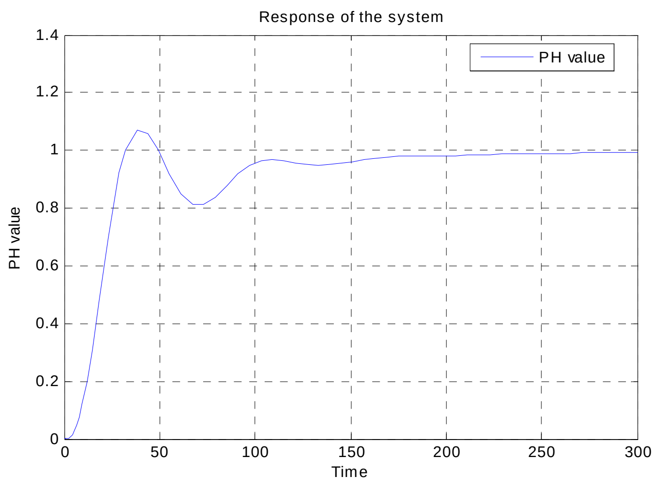


*Figure 6. Response of the system on step input*

## 3. CONCLUSIONS

Simulation results (figure 6, formulas 3 and 4) are almost the same as those presented in [1] in which parameters of PID controller has been obtained based on Ziegler Nichols method of the pH neutralisator . That means ANFIS can be used very successfully for modeling (identification) of pH neutralisator when experimental data are available.

## 4. REFERENCES


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